Test report | Explosion shock pressure resistance

1. Introduction

Filcoflex B.V. manufactures flexible connector systems for the food industry. These flexible connectors can be easily installed in so-called "Jacob pipework systems"[1]. Such systems are also frequently applied in areas or installations with an increased risk of explosion.

In many cases, such installations are protected against explosions by means of explosion venting. In these situations, the pressure resistance of the system depends on the reduced explosion pressure occurring after venting. In most cases, this reduced explosion pressure lies in the range of 0.5 to 1.5 bar_g. As a result, all components of the installation must be able to withstand this residual explosion pressure, including the flexible connector systems. This implies that these flexible systems[2] are subjected to mechanical stress caused by the pressure wave as well as thermal exposure from the flame.

Inburex Consulting GmbH was commissioned to develop and conduct a suitable test procedure for the evaluation of various flexible connector systems of identical diameter and length under realistic explosion conditions.

Werner van Loon, Managing Director of Filcoflex B.V., attended the tests and recorded visual documentation of the test programme.

The connector systems tested are described in Chapter 2 and are hereinafter collectively referred to as the "products". The materials tested are described in Chapter 3 and are hereinafter collectively referred to as the "materials".

2. Tested connector systems

The tested products were manufactured by Filcoflex B.V. in accordance with its normal production practices.

The products tested were equipped with the following connector systems:

- Jacob connection type FSC
  - Hereinafter referred to as the "FSC connector"
- Jacob connection type FDM
  - Hereinafter referred to as the "FDM connector"
- Tri-clamp connection type LFR
  - Hereinafter referred to as the "LFR connector"
- Hoseclamp connection type KLB20
  - Hereinafter referred to as the "KLB connector

3. Tested materials

The tested products were manufactured by Filcoflex B.V. in accordance with its normal production practices.

For therse products the following materials were used and tested:

- PU-UF1 (Ether based Poly Urethane 1mm)
- PU-UF3 (Ether based Poly Urethane 3mm)

[1] Fr. Jacob Söhne GmbH & Co. | Niederfeldweg 14 | D-32457 Porta Westfalica | Germany
[2] Some of these flexible systems were statically tested by water pressure tests up to a pressure of 1 Bar_g

4. Testing procedure

The explosion tests were carried out in a 1 m³ vessel. The test procedure was performed in accordance with ISO 6184/1 and DIN EN 14034/1 and -2. Detailed information regarding the test procedure is provided in the appendix. The following figures show the technical schematic and practical details of the explosion test rig.

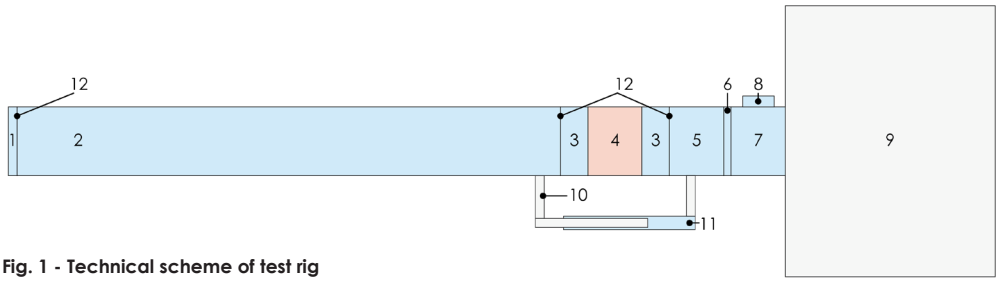


Fig. 1 - Technical scheme of test rig

No.	Description	No.	Description
1	Jacob cover plate/plastic sheet (Venting area)	7	Flange adapter DN 250mm (Existing) | Pressure sensor
2	Jacob welded pipe DN 250mm | L = 2000mm	8	Jacob cover plate for venting to adapt necessary explosion pressure
3	Jacob Hose connection (KLB only) DN 250mm | L = 100mm	9	1m³ vessel Pressure sensor
4	Flexible hose to test	10	Pipe with square profile Edge L = 40mm
5	Jacobs welded pipe DN 250mm | L = 200mm	11	Pipe with a square profile Edging L = 80mm
6	Jacobs connecting flange DN 250mm | L = 48mm	12	Normal/quick connect pull rings

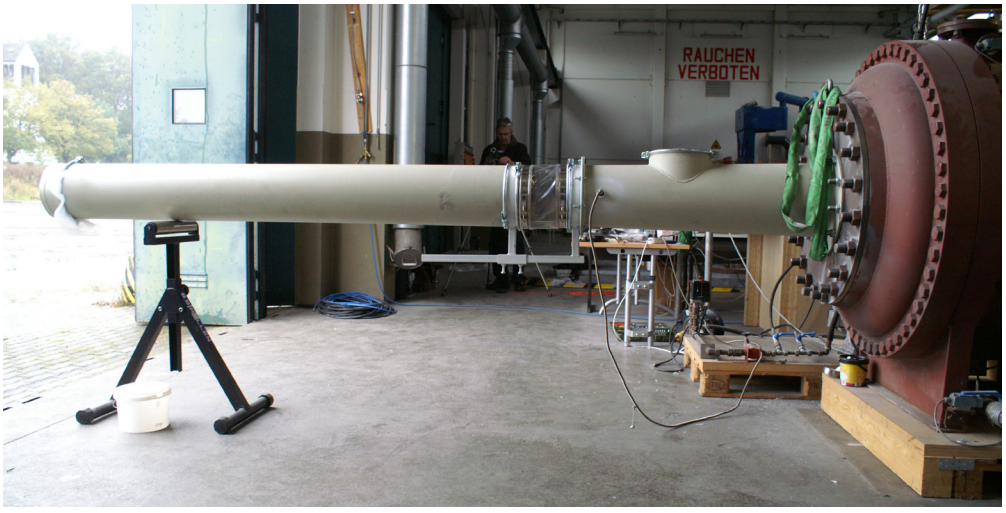


Fig. 2 - Practical application of the test rig

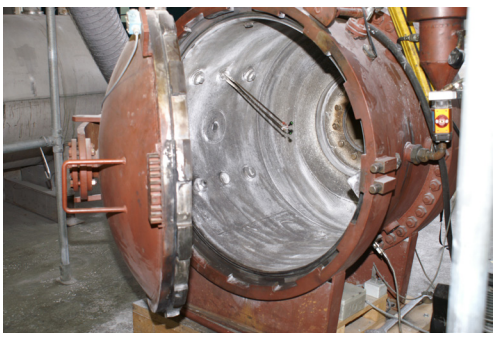
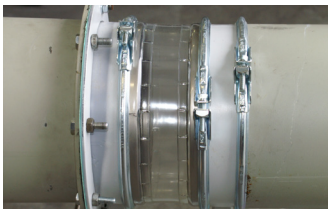


Fig. 3 - Front view of 1m³ vessel and venting area

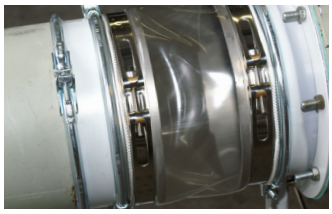
Achieving a reduced explosion pressure of 2 bar_g proved challenging; therefore, preliminary tests were conducted to optimise the test parameters.

The Jacob pipework system was sealed with a 0,05mm venting foil, typically applied in a double layer. Detailed test conditions are provided in the appendix.

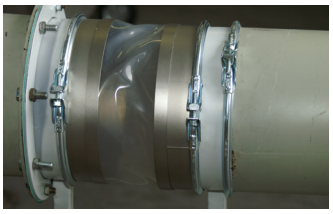
The following figures show the flexible connector systems tested. Please note that the products shown in the separate images are not the actual tested products; the products shown in the installation images are the ones that were tested.



FSC connector



KLB connector



FDM (left) & LFR (right)connector

Fig. 4 - Flexible connector systems

5. Test results

The individual test results of the tested connector systems, including the preliminary tests, are listed in the appendix. Appropriate photos and videos were recorded and archived by Filcoflex. A digital copy of these files is also archived at Inburex Consulting GmbH to ensure compliance with documentation and traceability requirements.

The following figure shows a typical real explosion, which was used as a practical test application.

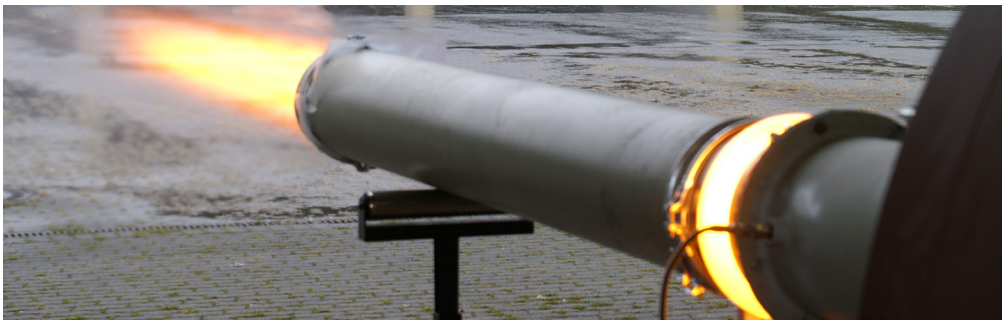


Fig. 5 - Jacob pipe and flexible connector system during the explosion

The pressure profiles during the explosion, both inside the 1 m³ vessel and upstream of the flexible connector system, were measured using pressure sensors.

The following figure provides an overview[3] of the explosion pressure ranges recorded for the different connector systems at the various pressure sensor locations.

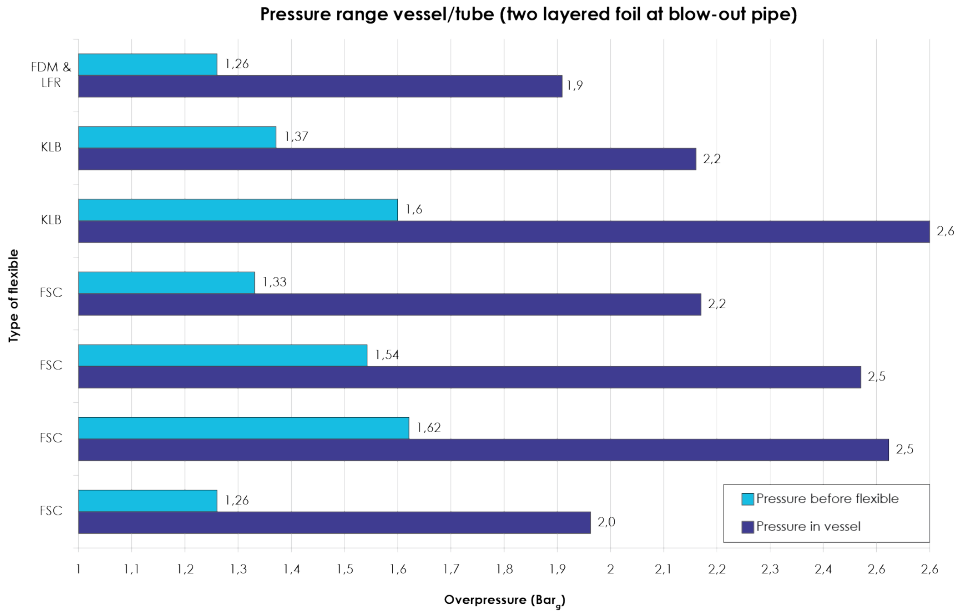
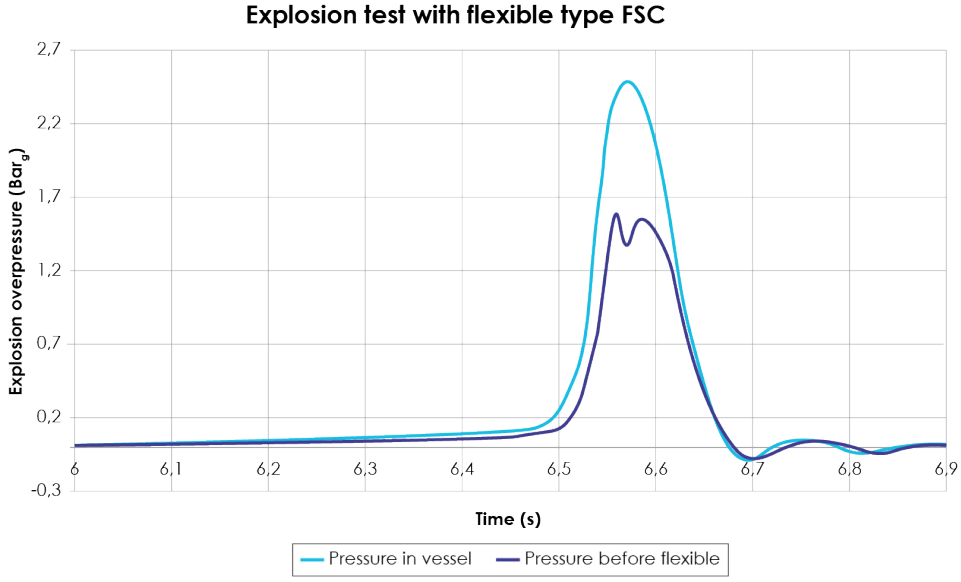


Fig. 6 - Maximum explosion pressure ranges of the test series

It can be observed that the explosion overpressure inside the 1 m³ vessel is in the range of 2 to 2,5 bar_g.

The diagrams in figure 7 show typical explosion pressure profiles[4] recorded during the testing of the different flexible connector systems.



[3] As data acquisition and/or video recording failed during some tests, only those tests for which both pressure data and corresponding video recordings were available have been considered in this evaluation.
[4] The K_{ST} values measured during the tests with the flexible connectors installed are in the range of 42 to 50 $bar \cdot m \cdot s^{-1}$.

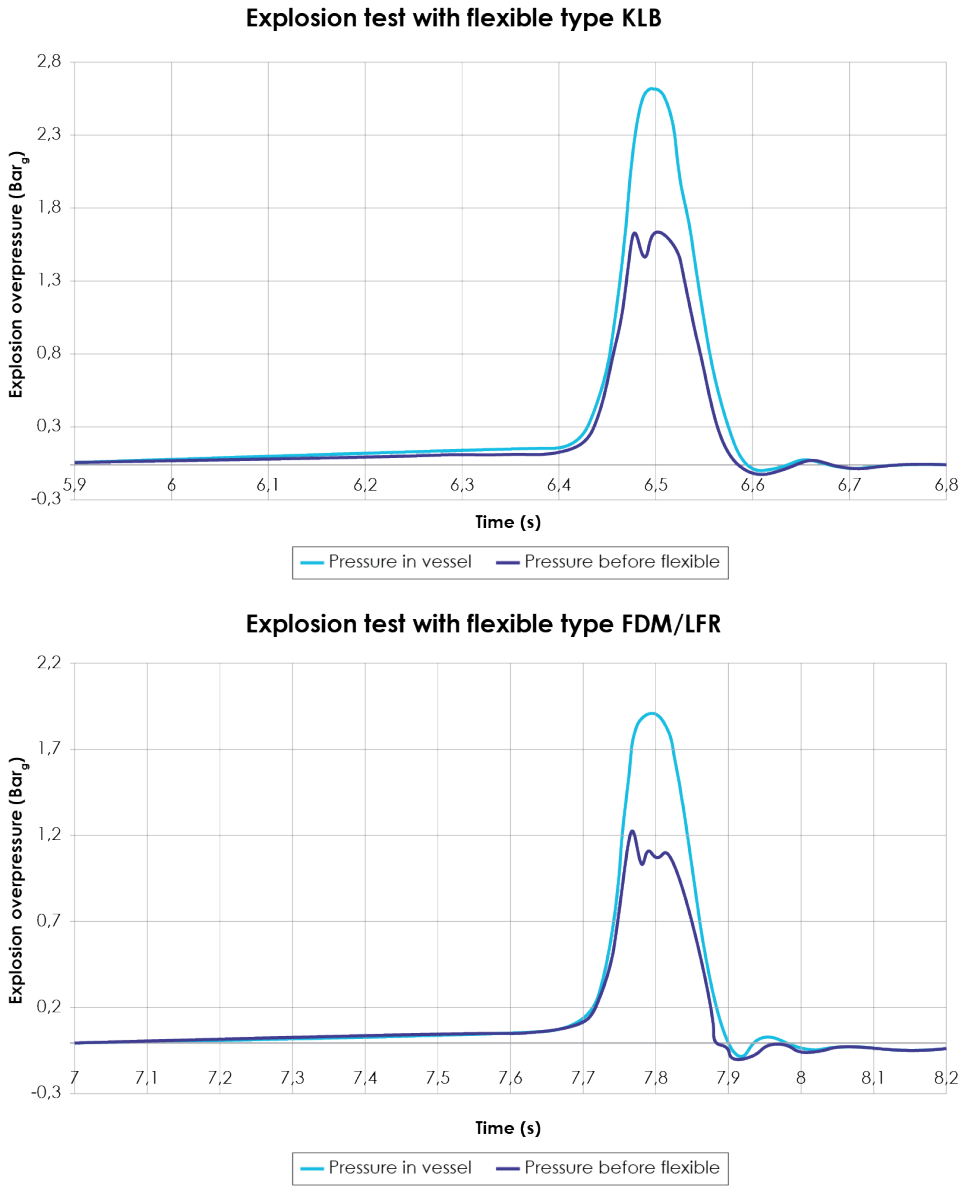


Fig. 7 - Typical pressure signal of both sensors

The following figures show the different connector systems before and after the explosion tests.

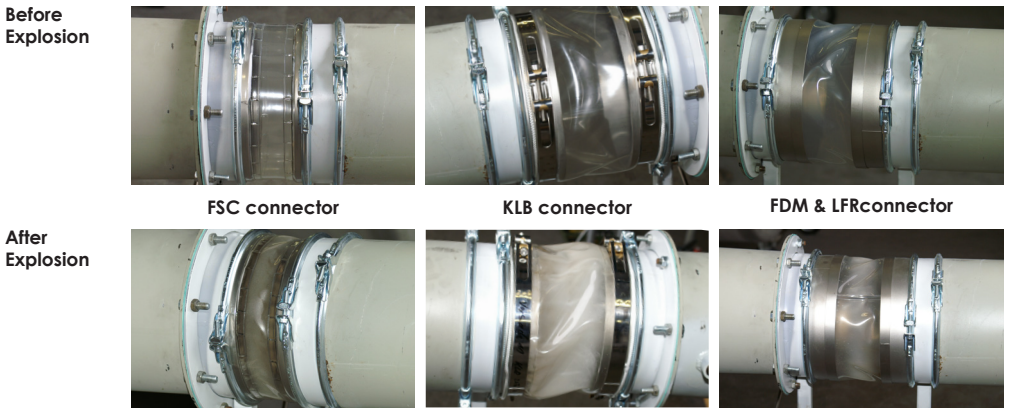


Fig. 8 - Comparison of the connector types before and after the explosion

6. Summary

In summary, it can be stated that the duration of the explosion, i.e. the increase in explosion pressure from ignition to the maximum value and the subsequent decrease to atmospheric conditions, is on average 200 ms.

An average explosion overpressure of 1,3 bar_g loads the connector systems for approximately 50 ms. In addition, the flexible connectors are exposed to thermal stress due to the high flame temperature.

It can be observed that, on the one hand, thermal stress partially caused a change in the colour of the flexible connectors. On the other hand, no failure or rupture of the flexible components was observed as a result of the applied mechanical stress.

Name: Werner van Loon
Function: Managing Director
Date: 02/07/2026

[5] The Willem-Jost-Institut is the research and testing laboratory of INBUREX GmbH

7. Appendix

In the following section, detailed information on the test procedure is provided.

A. Product characteristics of the used material corn starch
Nature of the sample: White and solid powder
Median value: 25µm
Moisture content: 9,1 wt.%
Type of explosive atmosphere: Dust-air mixture with the following safety properties

Safety Properties of corn starch[6] (Sample number 191)

Mass fraction < 71µm	100 wt.%
Mass fraction < 32µm	80 wt.%
Mass fraction < 20µm	43 wt.%
Median value D_{50}	22 µm
Lower explosion limit	60 g/m³
Maximum explosion pressure	10,6 Bar
K_{ST}-constant	143 m×Bar/s
Dust explosion class	ST 1
Auto ignition temperature (GG-oven)	440 °C
Minimum igition temperature of a dust layer	420 °C
Burning index	3 BI

B. Characeristics of the test rig
Dimensional sketch of the test rig
Dust-dispersion system: Baffle plate
Dust concentration during the tests: 500 g/m³
Explosion pressure during the tests: 1,5 to 2,8 Bar_g
Ignition energy: 2×5 kJ Pyrotechnical ignitors[7]
Ignition delay time: 0,6 s

C. Characteristics of the explosion isolation system
Type of explosion sensor: Pressure detection - 2× piezoelectric transducers type 701A with charge meter type 5015A[8]
Location of the pressure transducers: Middle of the explosion chamber and in front of the flexible connector system. (See figure 1 and 2)

D. Results of the experiments
In the following section, the individual test results are presented in two tables, as two separate data acquisition files were used.

Data series	Internal number of test sequences. The flexible connector tests started after test number 9.
Weight	Dust concentration during the tests (g/m³)
Sensor	Kanal 1 represents the pressure sensore in the 1m³ vessel Kanal 2 represents the pressure sensore before the flexible connector system.
Pressure	N.d. means that the data transmission between the pressure sensor and computer has failed.

[6] Source: GESTIS-STAUB-EX-Datenbank, sample no. 191 [http://bgia-online.hvbg.de/STAUBEX/explosuche.aspx]
[7] Supplier of the ignitors: Fr. Sobbe GmbH, Fabrik elektrischer Zünder, Beylingstraße 59, G-44329 Dortmund
[8] Kistler Instrumente G,bH, Daimlerstraße 6, G-73760 Ostfildern

The following table represents the test results of the first data file in its original version.

Series	Weight	Sensor	Test note	Pressure
0	250	Kanal 1	Drucktest I	0,58
1	250	Kanal 2	Drucktest I	0,52
2	250	Kanal 1	Drucktest III Folie 4fach	0,45
3	250	Kanal 2	Drucktest III Folie 4fach	0,14
4	500	Kanal 1	Drucktest IV Schweißfolie 1fach	1,58
5	500	Kanal 2	Drucktest IV Schweißfolie 1fach	0,84
6	500	Kanal 1	Drucktest mit kompensator Schweißfolie 1fach	1,72
7	500	Kanal 2	Drucktest mit kompensator Schweißfolie 1fach	0,88
8	500	Kanal 1	Drucktest mit Entlastung und Rohrverlängerung	1,94
9	500	Kanal 2	Drucktest mit Entlastung und Rohrverlängerung	1,11
10	500	Kanal 1	Test 1 - Montag-test doppel folie	1,91
11	500	Kanal 2	Test 1 - Montag-test doppel folie	1,26
12	500	Kanal 1	Test 2 - Montag-test doppel folie	0,06
13	500	Kanal 2	Test 2 - Montag-test doppel folie	1,42
14	500	Kanal 2	Test 3 - Montag-test doppel folie	1,47

The following table represents the test results of the second data file in its original version.

Series	Weight	Sensor	Test note	Pressure
0	500	Kanal 1	Versuch4 - montag doppel folie	N.d.
1	500	Kanal 2	Versuch4 - montag doppel folie	1,45
2	500	Kanal 1	Versuch5 - 2× folie FSC	N.d.
3	500	Kanal 1	Versuch7 - FSC doppel folie	2,52
4	500	Kanal 2	Versuch7 - FSC doppel folie	1,62
5	500	Kanal 2	Versuch8 - FSC doppel folie	1,54
6	500	Kanal 1	Versuch8 - FSC doppel folie	2,47
7	500	Kanal 1	Versuch9 - FSC doppel folie	2,17
8	500	Kanal 2	Versuch9 - FSC doppel folie	1,33
9	500	Kanal 1	Versuch10 - KLB doppel folie	2,6
10	500	Kanal 2	Versuch10 - KLB doppel folie	1,6
11	500	Kanal 1	Versuch11 - KLB 2× folie	2,49
12	500	Kanal 1	Versuch12 - KLB 2× folie	2,16
13	500	Kanal 2	Versuch12 - KLB 2× folie	1,37
14	500	Kanal 1	Versuch13 - FSC 4× folie 2× Aluinlay	2,79
15	500	Kanal 2	Versuch13 - FSC 4× folie 2× Aluinlay	2,14
16	500	Kanal 1	Versuch14 - FDM 4× folie 2× Aluinlay	2,81
17	500	Kanal 2	Versuch14 - FDM 4× folie 2× Aluinlay	1,89